INVESTIGATIVE STUDY ON COMMON CURING METHODS IN REDUCING PLASTIC SHRINKAGE IN CONCRETE SLABS

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ABSTRACT

Concrete hydration process is an action between the mixing of cement and water. The process produces heat release which can turn into a harmful reaction if the rate of heat released is higher than the concrete bleeding. The heat released will lead to shrinkage which every single concrete structure will be experiencing. The initial concrete shrinkage occurred can be classified as plastic shrinkage which is the most vital shrinkage that needs to be preserved. The main objective of this study is to investigate the methods to control shrinkage in concrete slabs using common curing techniques used in the construction industries. This study focused on using different curing methods on concrete slabs. Five different slabs were used as the testing samples for three common curing techniques; air dry, wet burlap sheeting and water spray curing. For wet burlap sheeting and water spraying techniques, two types of curing durations had been applied; one day and three days of curing had been practiced. All of the slabs were stored and tested at an open space which considers being the same environment in the construction. The test involved using mechanical strain gauge that indicated shrinkage readings through the movement of locating discs placed on the slabs. The testing of each of the slabs has been done after one day of concrete setting and continued tested until the fourth day after the concrete was set. The results and observations showed even though air dry curing method did not involve moisture contact other than the mixing water, the overall analysis showed that it was a better curing technique than using wet burlap sheeting. Water spray curing technique generated the most effective curing technique among other curing techniques used in this study.

ABSTRAK

Proses penghidratan konkrit merupakan tindak balas campuran antara simen dan air. Haba dilepaskan sebagai reaksi terhadap tindak balas tersebut yang mana boleh menjadi berbahaya sekiranya kadar haba yang dibebaskan tinggi daripada air yang keluar dari konkrit. Pembebasan haba boleh membawa kepada pengecutan konkrit. Pengecutan konkrit pada peringkat permulaan boleh dikategorikan sebagai pengecutan plastik. Objektif utama kajian ini adalah untuk menyelidik kaedah bagi mengawal pengecutan lantai konkrit dengan menggunakan proses pengawetan yang biasa digunakan di sektor pembinaan. Lima bahan kajian yang berbeza telah digunakan untuk tiga jenis kaedah pengawetan; pengeringan udara, guni basah dan semburan air. Bagi kaedah guni basah dan semburan air, dua tempoh pengawetan telah diaplikasikan; satu hari dan tiga hari pengawetan. Kesemua lantai konkrit disimpan dan diuji di kawasan terbuka yang dianggap mengalami situasi yang sama seperti kawasan pembinaan. Ujian menggunakan tolok terikan mekanikal menunjukkan bacaan bagi pengecutan melalui pergerakan lokasi cekera yang telah diletakkan di atas konkrit. Ujian bagi setiap lantai konkrit dilakukan setelah sehari tempoh bancuhan konkrit sehingga hari keempat selepas konkrit siap dibancuh. Walaupun kaedah pengeringan tidak melibatkan air, tetapi hasil kajian dan pemerhatian menunjukkan kaedah ini lebih efektik berbanding dengan kaedah yang menggunakan guni basah. Kaedah semburan pula terbukti sebagai kaedah terbaik di antara kaedah-kaedah lain yang telah digunakan dalam kajian ini.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete is the most common construction material. Concrete commonly composed of cement, aggregate and water. Concrete solidifies and hardens after cement mixed with water due to a chemical process known as hydration; hydration process is a chemical reaction that takes placed when cement and water are mixed together. Concrete is strong in compression strength but weak in tension strength. Concrete is used to make pavements, pipe, architectural structures, foundations, roads, bridges, walls and even boats.

One of the most common defects in concrete is the concrete shrinkage, particularly after each of concrete setting will undergo shrinkage. Time dependent strains in concrete have a significant effect on the structural behaviour and must be considered in the engineering design and the strains may be; creep due to stress or shrinkage due to moisture loss (Chern and Young, 1989). Concrete is subjected to changes in volume which affects the long term strength and durability. The volume changes in concrete due to shrinkage can lead to the cracking of the concrete and that can be the major reason for a concrete destruction. It is quite impossible to make concrete which does not shrink and crack. The question is how to reduce the shrinkage in concrete.

Shrinkage is used to describe the aspects of volume changes in concrete due to loss of moisture at different stages due to different reasons. For example, theoretically, at the early stage of concrete setting, the volume of concrete will be reduced due to heat

released from the concrete hydration process. Hydration process is a process whereby cement and water is mixed. Shrinkage can be classified into a variety of ways; such as plastic shrinkage, drying shrinkage, autogeneous shrinkage and carbonation shrinkage. But the most common type of shrinkage is plastic shrinkage and drying shrinkage.

Plastic shrinkage occurs soon after the concrete is placed in the formworks while the concrete is still wet. This type of shrinkage usually occurs in slab and wall construction. It is characterised by the appearance of surface cracks. Loss of water by evaporation from the surface of concrete or by the absorption by aggregate is believed to be the reasons of plastic shrinkage. The loss of water results in the reduction of volume, due to that the concrete shrinks. High water cement ratio, badly proportioned concrete, rapid drying, greater bleeding and unintended vibration are some of the reasons for plastic shrinkage.

Drying shrinkage is an everlasting process when concrete is in drying condition, due to the loss of moisture from hardened concrete. Excess water leaves the system as water did not consumed during hydration process. As a result, the concrete shrinks. Generally, the higher the excess water content, the higher the shrinkage potential. Drying shrinkage depends on relative humidity and temperature. Other factor affects drying shrinkage are type, content and proportion of constituent materials. Using concrete with a higher drying shrinkage increases the risk of the concrete floor performance.

1.2 PROBLEM STATEMENT

The concrete must be workable and cohesive when plastic, then set and harden to give strong and durable concrete. Thus, to make a concrete structure that workable, plastic shrinkage control should be taken into action. Concrete shrinkage is subjected to changes in volume due to the main causes of temperature, wind, surrounding and etc.. Thus, it is difficult to make concrete which does not shrink. The prior is how to reduce the plastic shrinkage in concrete. The loss of water results in reduction of volume, because of that the concrete will shrink. In most cases, shrink will cause cracks to appear but only if it is involving a large area of concrete such as slabs.

The shrinkage will cause increasing the risk of the floor performance due to change of the initial concrete size. The concrete with a higher shrinkage values will increase the risk of concrete performance. Therefore, this study will help to investigate the ways or methods in reducing or controlling the development of the shrinkage in the early stage of concrete setting. In doing so, a variety of slab samples need to be required to observe the occurrence of shrinkage and the readings. In general, this investigation needs a lot of laboratory works and also literature review. The outcome of the study will be the comparison and recommendation on methods of reducing plastic shrinkage in concrete slabs by using common curing techniques in the construction area.

1.3 OBJECTIVES OF THE STUDY

In the process of undergoing the investigation of methods to control plastic shrinkage in concrete slab, the properties and the behaviour of the concrete itself should be known to reduce the shrinkage values on concrete slabs. Thus, the behaviour of plastic shrinkage on concrete slab by literature review should be studied.

By understanding the properties and behaviour of the study materials and acquiring the related reasons, sources and solutions for the problems stated, the next approach is to do laboratory works. The laboratory works seeks to apply various methods of reducing the shrinkage cracks. The investigation is also to recommend the methods obtained. Consequently, a method should be found more reliable than the others. The methods that will be investigated are among the common curing techniques used in the construction industries.

1.4 SCOPE OF STUDY

In this study, the focus is on the production of concrete slab with a minimum amount of shrinkage. Shrinkage can cause volumetrically and structurally problem in order of producing a good quality concrete slab. Thus, the investigation can begin by studying the concrete slab shrinkage behaviour.

The parameters of the investigation can be continued with literature review to understand the methods to control the occurrence of shrinkage using common curing techniques. This process can be done by reviewing the previous studies or researches such as journals, books, including article that suggested variety of methods to resolve the matter. The specified methods that will be focused on during the investigation in literature review are about the curing methods; air dry, burlap sheeting and water spraying curing techniques.

All the investigations involved are using experimental or test conducted in the concrete laboratory. The laboratory work is to observe and to execute the methods obtained from the literature review. The investigation of the study is mainly during the early production of the concrete slab which is the plastic shrinkage of concrete.

1.5 SIGNIFICANT OF STUDY

This investigation can help to determine the most effective curing methods in controlling concrete shrinkage so that the occurrence of shrinkage will no longer be a volumetric problem to the structure. The investigation can be contributed to good application of concrete by giving the opportunity for the student to undergo laboratory work while reviewing the properties of concrete that needs to be controlled in reducing the plastic shrinkage values.

There are few studies have undertaken to determine the most effective curing methods in controlling plastic shrinkage values in concrete member. Some of the cases involved in influencing shrinkage are the environment, aggregate, sample handling and etc.. Therefore, this investigation will consider several of curing techniques that has been used in the construction in order to obtain the methods in reducing shrinkage. The types of curing methods that will be used are air dry, burlap coating and also water spraying curing techniques. It is hoped that the investigation will be the sequel of efforts in controlling shrinkage cracks in construction in the future.

1.6 CONCLUSION

The characteristics of shrinkage have been discussed throughout this chapter in order to identify the problems that might occur related to its matter. Based on the problems gained, the objectives to undergo the present study were clarified. The main objective in this study is to investigate the most effective curing method among common curing methods used in the construction industries in order to reduce and control plastic shrinkage in concrete slabs. The scopes of study which lead to having laboratory works were also been determined to achieve the objectives. The sequel for this chapter is to study and identify various techniques to be used in the laboratory work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The time-dependent properties of concrete have been researched since the early decades of the last century. The researches included various types of shrinkage such as; the shrinkage of hardened concrete due to drying is referred to as drying shrinkage, while plastic shrinkage is used to describe the shrinkage of fresh concrete and also autogenous shrinkage which occurs when a concrete can self desiccate during hydration process. Shrinkage results in reduction of volume that will not stop from continuing to occur. **Figure 2.1** shows the flow of concrete shrinkage values for more than one hundred days from the research of Chern and Young, 1989.

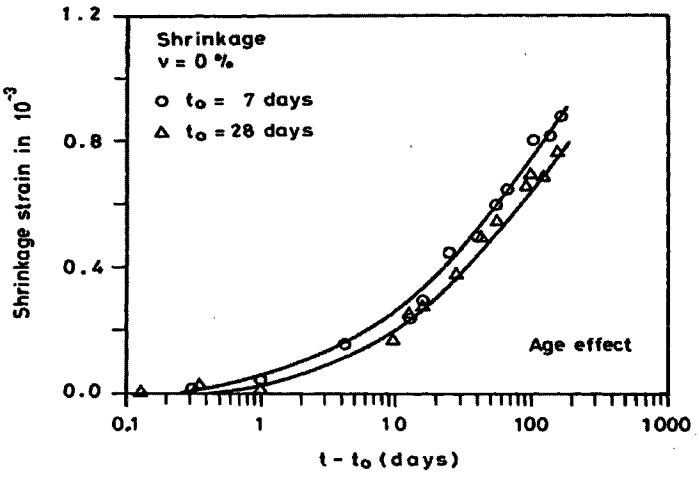

Figure 2.1 : The continuity of concrete shrinkage

Source : Chern and Young (1989)

Through the observation of several studies, various elements and properties of concrete that have been studied to overcome the shrinkage matter. But sometimes, the initial cause is not because of the production of the concrete but more related to the nature or surrounding. Early shrinkage strains can be developed by subjecting the concrete elements to different environment conditions during their early storage period (Barr et al , 2003). Chern and Young, 1989, have proven that higher temperature increases the creep rate of plain concrete.

During the first few hours concrete is still in a semifluid or in a plastic state, from where the term plastic shrinkage (Kronlof et al., 1995). At this stage, cementitious materials such as concrete go through negative volumetric variations, due to chemical reaction of hydration process. Then, water will lost due to evaporation or heat released.

Shrinkage reduction is important for the concrete durability, as well as the strength, particularly in structures such as slabs, bridge deck overlays, tunnel linings and pavements. If large values of shrinkage developed they might reduce long-term durability.

According to a researcher, Barr et al, 2003, shrinkage is a complex phenomenon that can be influenced by many factors including the constituents, the temperature and relative humidity of the surrounding, the age when the concrete is subjected to the drying environment and the size of the structure or member. Other than that, based on another research done by Al-Amoudi et al, 2007, stated that, the sudden and continuous variations in temperature and humidity increase the enhancement the cracking of concrete due to expansion and contraction. The researches proved that the environment around the concrete plays a major role towards the production of shrinkage cracks.

2.2 PLASTIC SHRINKAGE

Fresh concrete is vulnerable to plastic cracking especially during hot, windy and dry weather conditions. Based on the observation on previous studies, plastic shrinkage cracks are typically observed in concrete elements with a high surface area; which the specimen tested with large area such as slabs that are subjected to early age drying.

Plastic shrinkage cracks often appear on large surface area concrete members within the first three to 36 hours after casting (Al-Amoudi et al, 2007). Cracking at early ages can accelerate deterioration, promote steel corrosion and cause significant durability concerns in the long run.

When the evaporation rate is higher than the bleeding rate, it is possible that high tensile stresses can be developed in the capillary pores in the surface zone of concrete that may be sufficient to exceed the tensile strength of concrete, especially at early age (Sivakumar & Manu, 2007). It may be noted that humidity can be one of the main factor to cope with the matter of the investigation of plastic shrinkage. High surrounding temperature can lead to high evaporation rate that can cause water to be evaporated; as a result the concrete will crack. Plastic shrinkage can result in cracking, especially under hot, dry and windy weather conditions; structures or elements having higher surface to volume ratios are prone to such cracking (Mora-Ruacho et al, 2009).

2.3 CURING

Plastic shrinkage normally occurs while the concrete is still wet. Preventing rapid drying of the surface of the concrete and adopting good curing practices are some of the precautions against plastic shrinkage cracking (Sivakumar & Manu, 2007). The most effective technique of overcoming plastic shrinkage cracking is by preventing the loss of water from the concrete surface by extended curing. The concrete curing duration also affects the development of shrinkage cracking (Sharon Huo & Ling, 2006). Based on the research from Al-Moudi et al., 2007 showed that extended duration of curing is often recommended to control plastic shrinkage. During the first week or so; by maintaining the proper temperature neither too hot nor too cold, that will have major impact on the quality of the finished work.

Proper curing of concrete structures is important to ensure that the concrete meet the subjected performance and durability requirements. Based on a research done by Andre et al., 2011, cement curing control allows an improved material monitoring, resulting in an optimize construction planning, safety of the construction process, helps

preventing accidents in construction works and also planning for the formwork placement and removal operations.

The development of concrete shrinkage is proportional to the rate of moisture or water loss from concrete. By applying curing after the initial setting of concrete could help to sustain the moisture in concrete. As the result, the likelihood of shrinkage readings can be decreased. When concrete is cured, water retained in concrete would help cement particles to continue to react with water and will develop enough tensile strength to resist contraction stresses. Finally, the continuous development of strength reduces shrinkage.

Curing process is the final stage in newly-placed concrete production. The objective of curing is to keep concrete to be saturated or as nearly wet to undergo cement hydration process. When concrete is properly cured, water that remains in the concrete would help cement particles to continue reacting with water during cement hydration process and to develop tensile strength to resist contraction stress. There are many types of curing that can be applied to ensure the relative humidity of the concrete can be controlled. Among all types of curing techniques, wet curing, dry curing and moist curing are the types of curing methods that usually being applied in the construction industries.

2.3.1 Moisture Curing

This type of curing can be done by covering the concrete surface with either burlap or with an impermeable sheet such as polyethylene. Besides that, liquid membrane-forming compounds can be sprayed on the concrete surface to ensure that the concrete remain saturated. Wet burlaps, cotton mat, the polyethylene blankets are good curing methods to limit shrinkage strain development (Sharon Huo & Ling, 2006).

Soon after placement, evaporation of the mix water of the concrete hydration creates shrinkage strains in concrete. The compound acts as a coating that defends the mix water to evaporate from the concrete surface in case of dry condition. Other than

reducing plastic shrinkage cracking, curing also significantly improve the strength of the concrete. A research by Al-Gahtani, 2010, proved that two days of cured concrete exhibited significant improvement in strength and other characteristics compared with concrete without curing.

In plain cement concrete, there is always some bleed water, therefore, this water will evaporate first if hot weather conditions prevail. Once all the bleeding water evaporates, water from fresh concrete will then start evaporating. A delay in the evaporation of pore water will enhance the strength development of hardening concrete thereby resisting the tensile stresses forced by the surrounding conditions. The delay can be done by applying moisture coating indicator such as burlap an impermeable sheet.

2.3.2 Wet Curing

The most effective method of curing is to keep the exposed concrete surfaces continuously moist. The concrete is saturated for a long term period after setting, the ideal condition for strength development and hydration of cement (Al-Gahtani, 2010). This type of curing technique usually applied a direct contact with water; therefore no sheeting indicator will be used. The application that can be used are water ponding, water spraying, etc.. In the concrete cured by wet curing method, the evaporation of mixed water is minimized. As a result, the concrete strength increased.

The curing becomes even more important if the concrete is subjected to hot and dry environments immediately after casting. Based on a study done by Al-Moudi et al, 2007 proved that the shrinkage strains in concrete specimen cured by covering them with wet burlap generated a less preferable result than the water ponding curing technique. **Figure 2.2 (a)** and **(b)** below shows the shrinkage strains results for both curing techniques.

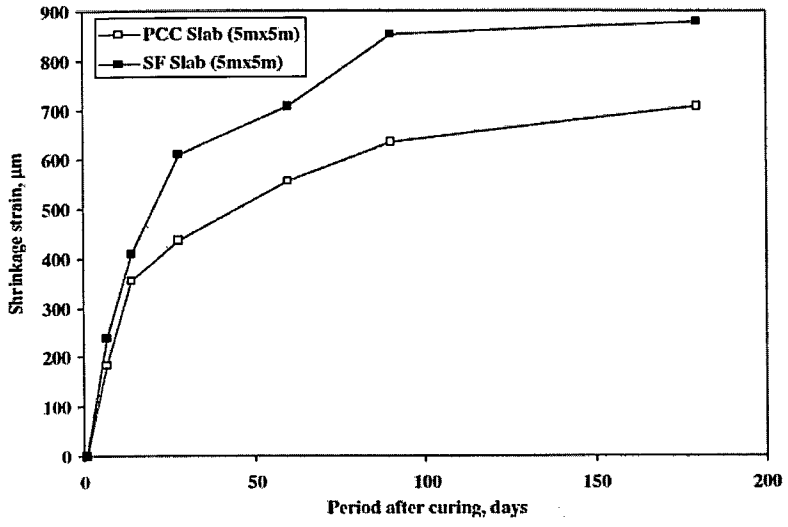

Figure 2.2 (a): Average shrinkage results for concrete specimen cured by covering them with wet burlap

Source : Al-Moudi et al. (2007)

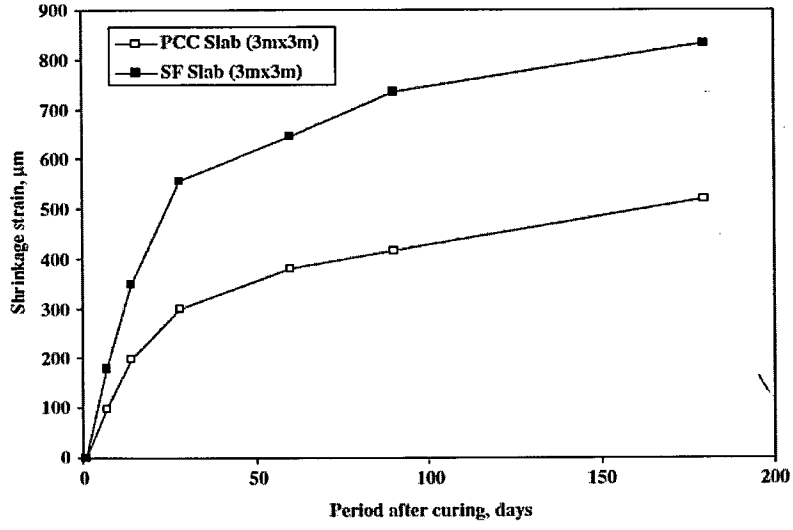

Figure 2.2 (b): Average shrinkage results for concrete specimen cured by water ponding

Source : Al-Moudi et al. (2007)

The figure by Al-Moudi et al., 2007 shows the reading of specimens using water ponding produced lower shrinkage strain than the specimens cured by covering them with wet burlap. This proved that while the concrete hardened, a special attention must be given to the concrete, in such keeping the concrete surfaces wet. Other than that, based on various studies done by the past researchers proved that by applying wet curing methods can improve the strength of concrete.

2.3.3 Air Dry Curing

Other than wet and moist curing methods, dry curing or air-dry curing is one of the types of curing that can be practiced. Besides controlling the rapid loss of water, curing might also held to control temperature since this affects the rate at which cement hydrates. Air dry curing is the easiest way to perform curing process by exposing the concrete to the atmosphere and letting the concrete undergo cement hydration process. Dry curing is the easiest practiced method, but it only has a little advantage compare to other methods.

Even though all curing methods showed an increase of compressive strength with age, the compressive strength of using burlaps is higher compared to air-dry curing compound (Hani et al., 2005). The statement from Hani et al., 2005 showed that curing method using wet burlap produced higher compressive strength than the concrete cured using air dry technique. The results basically were due to the exposure of concrete with moisture or water. Air dry curing techniques which did not involve water contact with the specimens indicate lower compressive strength. Theoretically, air dry curing technique will result in the highest shrinkage readings than the other curing techniques which involved moisture contact towards the concrete.

Curing techniques using air drying are utilized in the situation where curing by water ponding is not practical (Al-Gahtani, 2010). With the increasing scarcity of water, there is pressure on the construction industries to decrease its consumption of water. This is the main problem in countries where natural water sources are lacking and air dry curing techniques might have been applied onto concrete structures.

2.4 APPLICATION

Based on the observation from the previous studies, there were many methods that have been applied according to the different compatibility of the concrete used and the type of shrinkage that need to be examined. The most effective yet economic technique of overcoming shrinkage of concrete is by concrete curing. Curing can be one of the methods that can be applied to control plastic shrinkage occurrence.

As the final decision making, curing techniques using wet burlaps sheeting were applied for the moist curing, water spraying technique for the wet curing technique option and also air dry curing technique will be applied onto the concrete slabs. The air dry curing also acted as the control sample to compare with the other curing techniques samples.

2.5 CONCLUSION

Shrinkage and plastic shrinkage characteristics have been determined throughout this chapter. Plastic shrinkage which normally occurs while the concrete is still wet lead to finding the most effective technique of reducing plastic shrinkage by using different curing methods. The curing methods that have been discussed in this are air dry, wet burlap sheeting and water spraying. Many sources of journals have been studied in order to understand the traits of each of the curing techniques. The chosen curing methods are the common curing methods used in construction industries. The methods to undergo laboratory work will be discussed in the next chapter.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Various types of shrinkage can occur after the production of concrete; plastic shrinkage, drying shrinkage, autogeneous shrinkage and carbonation shrinkage. These types of shrinkages occur by different reasons. Drying shrinkage defined as the shrinkage of hardened concrete due to drying, plastic shrinkage is used to describe the shrinkage of fresh concrete, while autogeneous shrinkage occurs when a concrete can independently dry out during hydration (Barr et al., 2003).

By reducing the concrete shrinkage, there are many methods that can be used to improve the volume changes factor and also long term durability aspect. Due to lack of formation of autogeneous and carbonation shrinkage, this type of shrinkage will not be considered in the investigation. Other than that, long-term investigation into drying shrinkage of concrete will also not be considered in the study due to lack of time for the period of study. Thus, this minimizes down to only investigate about plastic shrinkage and the methods to reduce shrinkage by using common curing techniques which are wet burlap sheeting, water spraying and air dry curing onto the concrete slabs.

3.2 FLOW CHART

Figure 3.1 below shows the outline of the investigation in determining the methods of reducing plastic shrinkage cracks in concrete slab:

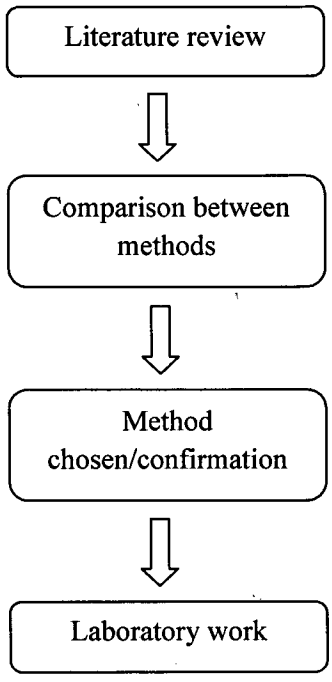

Figure 3.1 : Flow chart

3.3 LITERATURE REVIEW

This initial process is extremely vital in order to determine the variety of methods that can be used in reducing shrinkage in concrete. The review can be made and the methods can be gained by studying previous books, journals and articles that had been done by the past researches. For example, a research done by Sivakumar and Santhanam, 2007, stated that the precautions against plastic shrinkage include preventing rapid drying of the concrete surface and adopting good curing practices. This proved that a proper curing is vital in order to reduce concrete shrinkage.

3.4 COMPARISON BETWEEN METHODS

After obtaining various methods that can be used in reducing shrinkage, comparisons among the methods will be conducted in order to get the best methods to be investigated. For instance, a study by Mora-Ruacho et al., 2009, stated that plastic

shrinkage usually used the incorporation of fibres in concrete which limit crack opening. The occurrence of fibres in the concrete structure will restrain the concrete and reduces the shrinkage values. On the other hand, an investigative study by Sivakumar and Santhanam, 2007, confirmed that good curing practices like shrinkage reducing admixtures will reduce the formation of plastic shrinkage.

3.5 METHOD CHOSEN/CONFIRMATION

Based on the methods gained from reviewing previous literature, the methods that have been chosen to undergo the investigation are by applying curing process onto the concrete. Curing is one of the most economical yet practical that ones can apply in order to control plastic shrinkage. Other than that, the materials used in curing process are also easy to be found; such as, burlap and water rather than by using expensive fibres which is not that easy to be obtained at the laboratory. Curing is the final stage of controlling the production of concrete; after designing, batching, mixing and casting, which indicates that the investigative study will be seriously observed after the concrete is finished casting.

3.6 LABORATORY WORK

After discussing about the objectives in the introduction, some experiments need to be done in order to achieve those objectives which are basically to apply the methods to reduce plastic shrinkage in concrete slabs by using common curing techniques that usually been applied in the construction industries. Several plans before laboratory work will make sure the work will be more organized. The outline that has been planned is: list all of the materials and equipments that need to be used in the laboratory experiment and inform the laboratory officer about the experiment works that have been planned to do.

The stages of concrete production are designing, batching, mixing, casting and curing. The method chosen to be investigated in the study is curing, which is at the final stage. Due to that, all of the factors prior to the curing stage need to be standardised in order to achieve better results; such as the types of aggregate used in all the concrete